List of Questions

1. What type of lens and filters are recommended for ULS24, where can we source these components? 3

2. Are filters needed for fluorescence and chemiluminescence imaging, what types of filters are best suited for this type of application? 3

3. What types of operating temperature is needed for ULS24 function, how to perform temperature compensation. 3

4. Is the ULS24 Solution Kit a plug and play system? What other components are needed for it to function in my system. 4

5. How does ULS24 compare to photon multiplier tubes? Can ULS24 be used in applications that typically require a photon multiplier tube? 4

6. How does ULS24 compare to CCDs or cooled CCDs? Can ULS24 be used in applications that typically require a CCD chip? 4

7. Where can I find information about the registers and pin out of ULS24? 5

8. How can I connect ULS 24 to a host system, which could be a PC, a mobile device such as smartphone or tablet, or an embedded processor? 5

9. Can ULS24 communicate with Bluetooth or just a UART? 5

10. How big is the sensing area of ULS24? 6

11. How sensitive is ULS24? How is it measured? 6

12. What kind of FPS (frame per second) can ULS24 achieve? 6

13. What kind of linearity can ULS24 achieve? How is it measured? 7

14. Can multiple ULS24 devices be used in my system? If so, can I connect them to the same host MCU? 7

15. What is the range of integration time? 7

16. Can I use fiber optic light guides to feed signal to ULS24? 7

17. How does ULS24 compare to individual photo diode devices, at both device level and system level? 7

18. What is the quantum efficiency (QE) and fill factor of ULS24 pixels. How does QE change with wavelength? 8

19. Would it be possible to improve near infrared (NIR) sensitivity of ULS24 to make it optimal for certain type of fluorescence imaging? 8

20. How does ULS24 compare with a consumer CMOS such as the ones find in a smart phone? 8

21. What software can be used to access features of ULS24 and capture image? 8

22. What if I want to develop my own software to access the features of ULS24, but do not want to start from scratch? 9

1. What type of lens and filters are recommended for ULS24, where can we source these components?

We recommend 3 options to fit a lens system to ULS24: 1) Using a C mount lens system; 2) Use custom lens system provided by Anitoa or customers themselves; 3) Use an M-12 lens system for quick prototyping. For more details, please see Anitoa Application Notes: How to add optics to ULS24 Solution Kit. (http://www.anitoa.com/technology.html).

2. Are filters needed for fluorescence and chemiluminescence imaging, what types of filters are best suited for this type of application?

For fluorescence imaging emission filters specifically designed for fluorescence are required. If we use any light source other than laser, matching excitation filters are also required. For more details, please reference to Application Note on DNA quantification with Anitoa CMOS Fluorescent Imager. (http://www.anitoa.com/technology.html).

For chemiluminescence imaging, it helps to add a filter to narrow the sensing spectrum to match that of the chemiluminescence emission spectrum. For example, certain CLIA (chemiluminescence based immunoassay) calls for band pass filter centered on 430nm with a 50 - 100nm pass bandwidth. Having a filter help improve signal to noise ratio by filtering out background noises, especially that in the near infrared (NIR) range.

3. What types of operating temperature is needed for ULS24 function, how to perform temperature compensation.

ULS24 can operate normally and meet its sensitivity and signal to noise ratio up to 55 degree C. At 25 degree C or below, the temperature dependent noise is insignificant. Between 25 and 55 degree C, increase in temperature will result in the DC portion of the dark current to increase. This will in turn raise the dark output level when integration time is long. This can be eliminated by an algorithm that utilizes the on-chip junction temperature sensor. For more details about temperature compensation algorithm, please contact Anitoa tech support. (info@anitoa.com).

4. Is the ULS24 Solution Kit a plug and play system? What other components are needed for it to function in my system.

ULS24 Solution Kit is a plug-and-play system that includes everything: sensor module, an interface board, software and all cables and accessories to allow customers to perform system evaluation of the ULS24 device. The user needs to add his/her own optics (lens, filters) etc. Anitoa can provide help in selecting lens and filters.

5. How does ULS24 compare to photon multiplier tubes? Can ULS24 be used in applications that typically require a photon multiplier tube?

ULS24 can be used in place of photon multiplier tubes (PMT) in a wide range of applications that require low light sensing. PMTs have two operating modes: photon counting mode and integration mode. Although in photon counting mode, theoretically PMTs can sense individual photon incidences by generating corresponding pulses. Under most practical situations, PMT output pulses correspond to photo incidence in a probabilistic manner. I.e. pulses could go off due to noise in the system instead of a photon strike. Therefore in most cases, PMTs work in integration mode where it accumulates pulses for a given period of time as an average measure of light intensity level. In this mode, ULS24 can work in the same way and achieve similar sensitivity and signal to noise ratio than a PMT.

CMOS image sensor such as ULS24 is much cheaper, smaller and low power compare to a PMT. PMTs require sophisticated power supply system and signal conversion circuitry whereas CMOS image sensor only requires low voltage supply readily available in any electronic device and provides a digital output that can be directly read by processors.

Moreover, PMTs are semi hand-made. The device-to-device uniformity is poor. This means with PMT, every optical system needs to be individually calibrated.

6. How does ULS24 compare to CCDs or cooled CCDs? Can ULS24 be used in applications that typically require a CCD chip?

CCDs that are designed for medical and scientific applications are high quality image sensors with superior sensitivity and signal to noise ratio. However, CCDs are more expensive, requires external, dedicated signal acquisition electronics since CCDs outputs analog signals. Additional noises can be introduced in the system with CCDs during the process of converting very weak analog output signals to digital signals that a processor can use. Moreover, for low light sensing, CCD devices often has be to cooled to achieve desired signal to noise ratio performance.

Ultra low light CMOS imager such as ULS24 can achieve the sensitivity and SnR of a scientific CCD device without the hassle of dedicated additional electronics, the need for cooling and the high cost associated with CCD device itself and supporting electronics

7. Where can I find information about the registers and pin out of ULS24?

We have a detailed data sheet for ULS24 that includes pin out information, physical dimension information and register information, programming instruction etc. It is available to prospective customers who expressed interest.

8. How can I connect ULS 24 to a host system, which could be a PC, a mobile device such as smartphone or tablet, or an embedded processor?

The ULS24 device has a SPI interface as its main data and control interface. This is a 4 wire digital serial interface that is very popular in the embedded world. Most if not all microcontrollers on the market has one or more SPI interface port. So ULS24 can be connected to an embedded processor readily. To provide an interface to the PC or mobile device, we recommend using a microcontroller that has at least one SPI interface for ULS24 and an USB, or UART, interface to connect to a PC host.

To communicate with a mobile device, we recommend using a blue tooth bridge device to provide a link between ULS24 and a mobile device such as smartphone or tablet. For more information, please refer to Anitoa Application Note: how to interface ULS24 with an embedded processor.

The ULS24 solution kit comes with an interface board that bridges the ULS24 and PC using SPI and USB interfaces on each end.

9. Can ULS24 communicate with Bluetooth or just a UART?

Yes, see above.

10. How big is the sensing area of ULS24?

The sensing area of ULS 24 is 3.6 x 3.6 mm. It contains 24 x 24 = 576 pixels.

11. How sensitive is ULS24? How is it measured?

We use minimum detection light level threshold and associated signal-to-noise ratio (SnR) to describe the sensitivity of ULS24 chip. We believe this is the most relevant method to quantify the performance of the chip for its intended applications (sense light). Using 550nm narrow band light (~10nm bandwidth), ULS24 can detect 3E-6 lux of signal with typical 15dB of SnR. This is tested with 4s of integration time.

Note that we test our chip with 550nm monochromatic light source. This is most relevant to the intended applications where the signal of interest is in a narrow band. Since 550nm light has the least amount of radiometric energy for a given amount of photometric flux (meaning it is brightest to our eyes), this is the most challenging test condition. If we use ~2850k broad-spectrum white light to perform same test, the numerical value of ULS24 sensitivity will improve significantly. For example, ULS24 should be able to detect ~4E-7 lux of white light with ~15dB SnR.

Also ULS24 is capable of much longer integration time than 4s, up to 10's of seconds. So if the application allows for longer integration time, better low light sensitivity than the above described numbers can be achieved.

There are several chip parameters that contributed to ULS24's sensitivity; they are pixel responsivity, dark current, read out noises etc. For details of these parameters, please refer to ULS24 Datasheet.

12. What kind of FPS (frame per second) can ULS24 achieve?

ULS24 can achieve ~900 frame per second using 1ms integration time.

13. What kind of linearity can ULS24 achieve? How is it measured?

One of the key strength of ULS24 device is its excellent linearity. We have ULS24 evaluated at independent testing facilities according to EMVA1288 standard. In low gain mode, the non-linearity error is less than 0.5% and in high gain mode, it is less than 0.6%.

14. Can multiple ULS24 devices be used in my system? If so, can I connect them to the same host MCU?

Multiple ULS24 can be attached to the same SPI bus of a microcontroller (MCU). The MCU may need to use some GPIO pins as additional slave select (SS).

15. What is the range of integration time?

Integration time can span from several hundred micro second (us) to a few tens of seconds.

16. Can I use fiber optic light guides to feed signal to ULS24?

Using fiber optic light guide to transport light signal from a sample to the ULS24 is an excellent way in optics design. The advantage is 1, flexibility in spatial layout of the system; 2, better system level signal to noise ratio by achieving better isolation of the light signal from background light noise. Using fiber optic light guide means less light energy is transported to the sensor. However, given ULS24's high sensitivity, this rarely presents a problem in applications.

17. How does ULS24 compare to individual photo diode devices, at both device level and system level?

Although some discrete photo diodes can provide reasonable sensitivity for low light sensing, these are single pixel devices. Photo diodes also output weak analog signals that require sophisticated amplification signal conversion electronics. And the signals from photo diodes in low light sensing are prone to electronic noise contamination from signal amplification and conversion. ULS24 on the other hand is a true image sensor. ULS24 outputs clean digital signals.

18. What is the quantum efficiency (QE) and fill factor of ULS24 pixels. How does QE change with wavelength?

The QE of ULS24 pixel is 65% at 550nm (green). The filter factor is nearly 100%. QE drops off to about 34% at 400nm (blue) and 40% at 800nm (red to near infrared).

Although not officially characterized, ULS24 demonstrate reasonable to good sensitivity in UV range of 300nm to 400nm and infrared range of 800nm to 1100nm. For sensing at UV or IR bands, special lens material may be required. For example, for UV sensing, quartz, instead of glass lens material is desired.

19. Would it be possible to improve near infrared (NIR) sensitivity of ULS24 to make it optimal for certain type of fluorescence imaging?

It is possible to enhance NIR QE by a custom design of ULS24. In this case, we can adjust the EPI layer thickness in the process step to shift the QE peak to NIR range. There is a minimum order requirement for us to perform this customization.

20. How does ULS24 compare with a consumer CMOS such as the ones find in a smart phone?

Consumer CMOS image sensors typically has detection limit of 1 lux. ULS24 can detect 3e-6 lux narrow band signal with a few seconds of integration time. ULS24 is much more sensitive than consumer CMOS image sensor due to two factors: higher responsivity and lower dark current. The former allow ULS24 to respond to lower light level input and the latter allows ULS24 to use longer integration time (seconds to minutes) to capture more photons without saturating.

21. What software can be used to access features of ULS24 and capture image?

We provide a software called ULVision as part of the ULS24 Solution Kit. ULVision is optimized for low light-imaging for scientific applications. It uses USB HID interface and is thus plug-and-play (no drivers needed). ULVision allows the user to access all internal features of ULS24 with an intuitive graphic user interface (GUI). In addition to displaying images, ULVision outputs raw pixel data that can be copied and sent to other applications (e.g. Excel, Matlab) for further processing.

ULVision has some cool features such as "Intelligent Dark Subtraction". With this feature a dark frame can be taken and then subtracted from the captured image. The software automatic

compensates for differences such as junction temperature and other parameters between the dark frame and the captured image.

22. What if I want to develop my own software to access the features of ULS24, but do not want to start from scratch?

We offer a software development kit called ULVision SDK. It contains sample source code and libraries for the developers to expand on. The library contains an API (application program interface) to allow customers' application to call and access ULS24 hardware features.